How well can the combination of hISST and SLR replace GRACE?

A discussion from the point of view of applications

M. Weigelt, T. van Dam,
O. Baur, M.J. Tourian,
H. Steffen, K. Sośnica,
A. Jäggi, N. Zehentner,
T. Mayer-Gürr, N. Sneeuw

RUES | RESEARCH UNIT IN ENGINEERING SCIENCES

UNIVERSITÉ DU LUXEMBOURG

FACULTY OF SCIENCES, TECHNOLOGY AND COMMUNICATION

30.09.2014

IWF GIS LANTMÄTERIET AIUB ITSG

PROCESSING

A short overview

HLSST + SLR

High-low SST:

- 11 satellites with GPS

CHAMP	GRACE A	GRACE B
GOCE	MetOp A	MetOp B
TerraSAR X	TanDEM-X	
Swarm A	Swarm B	Swarm C

- accelerometer data used when available
- combination at the normal equation level

HLSST + SLR

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Details in Zehentner et al:
Non-dedicated satellite missions for time-variable gravity field recovery

Today: 14:30

HLSST + SLR

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Today: 14:30

SLR:

- 9 satellites

Lageos 1	Lageos 2	LARES
Starlette	Stella	Larets
AJISAI	Beacon-C	Blits

- gravity parameters together with station coordinates, ERP, geocenter and range biases
- combination at the normal equation level

HLSST + SLR

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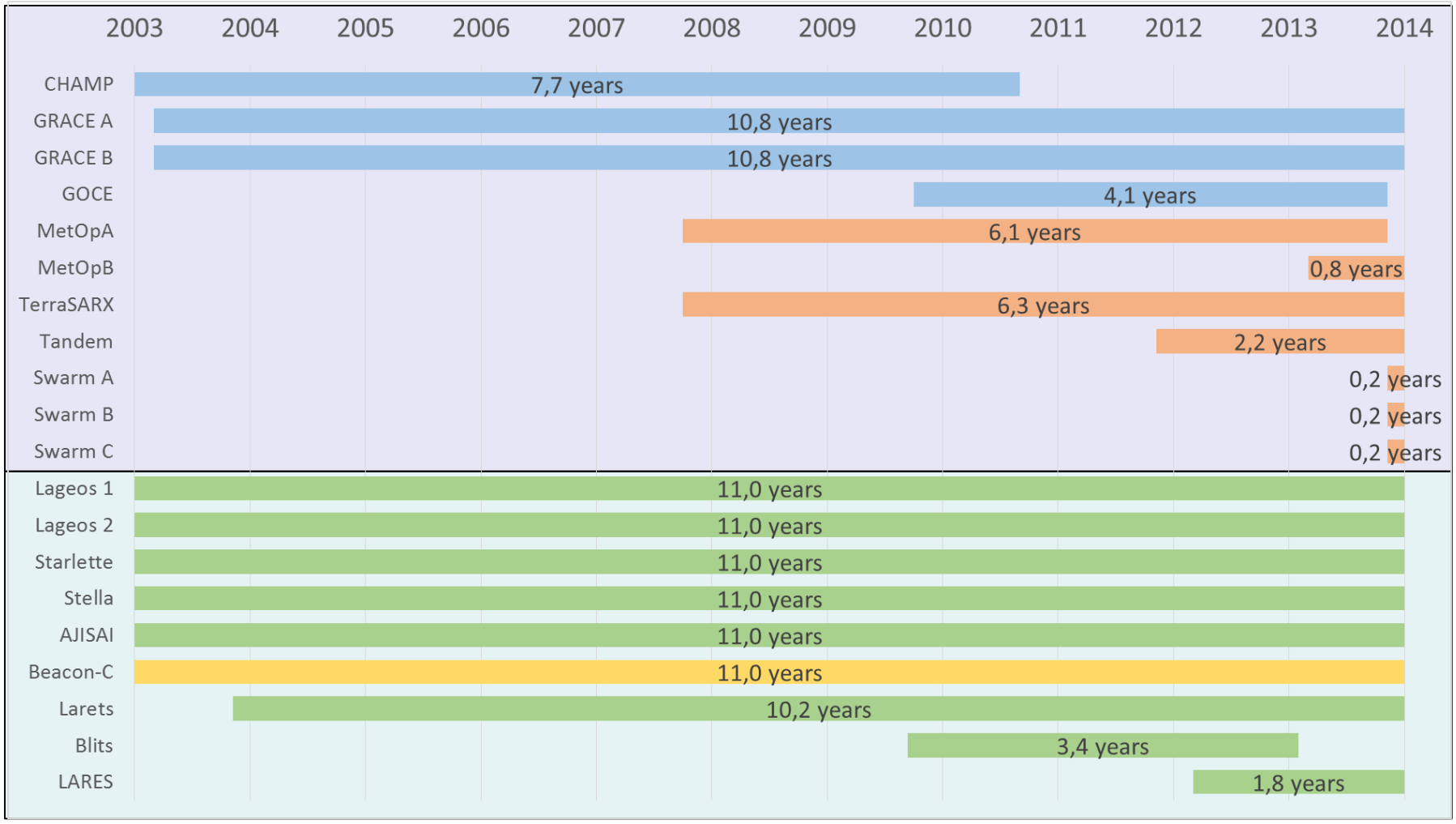
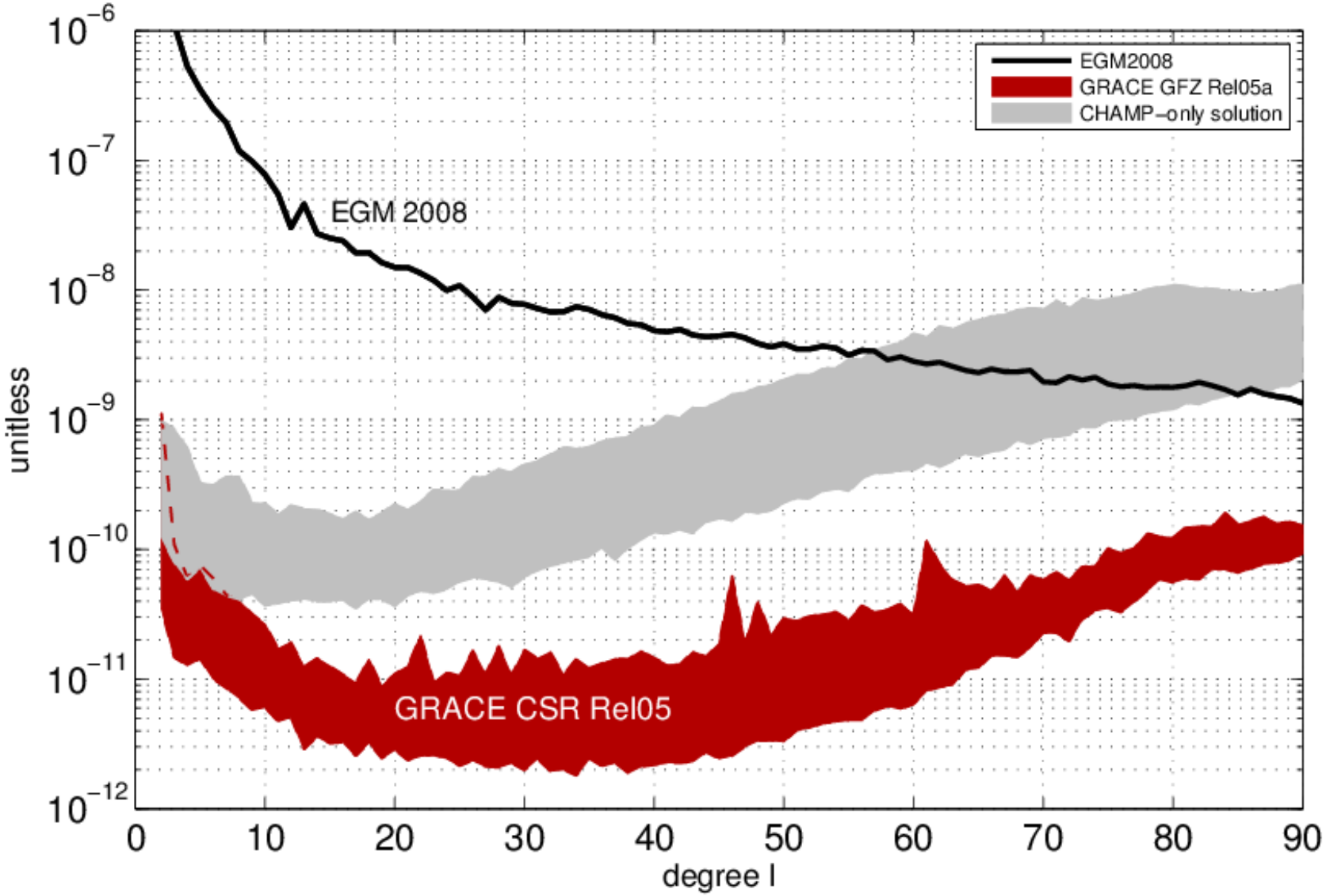
Details in Sośnica et al:
Time varying gravity from SLR, combined SLR and high-low satellite-to-satellite tracking data
Today: 14:15

Data availability



CHAMP-only


EGM2008
GRACE GFZ Rel05a
CHAMP–only solution
EGM 2008
GRACE CSR Rel05
unitless
degree l
10^{-6}
10^{-7}
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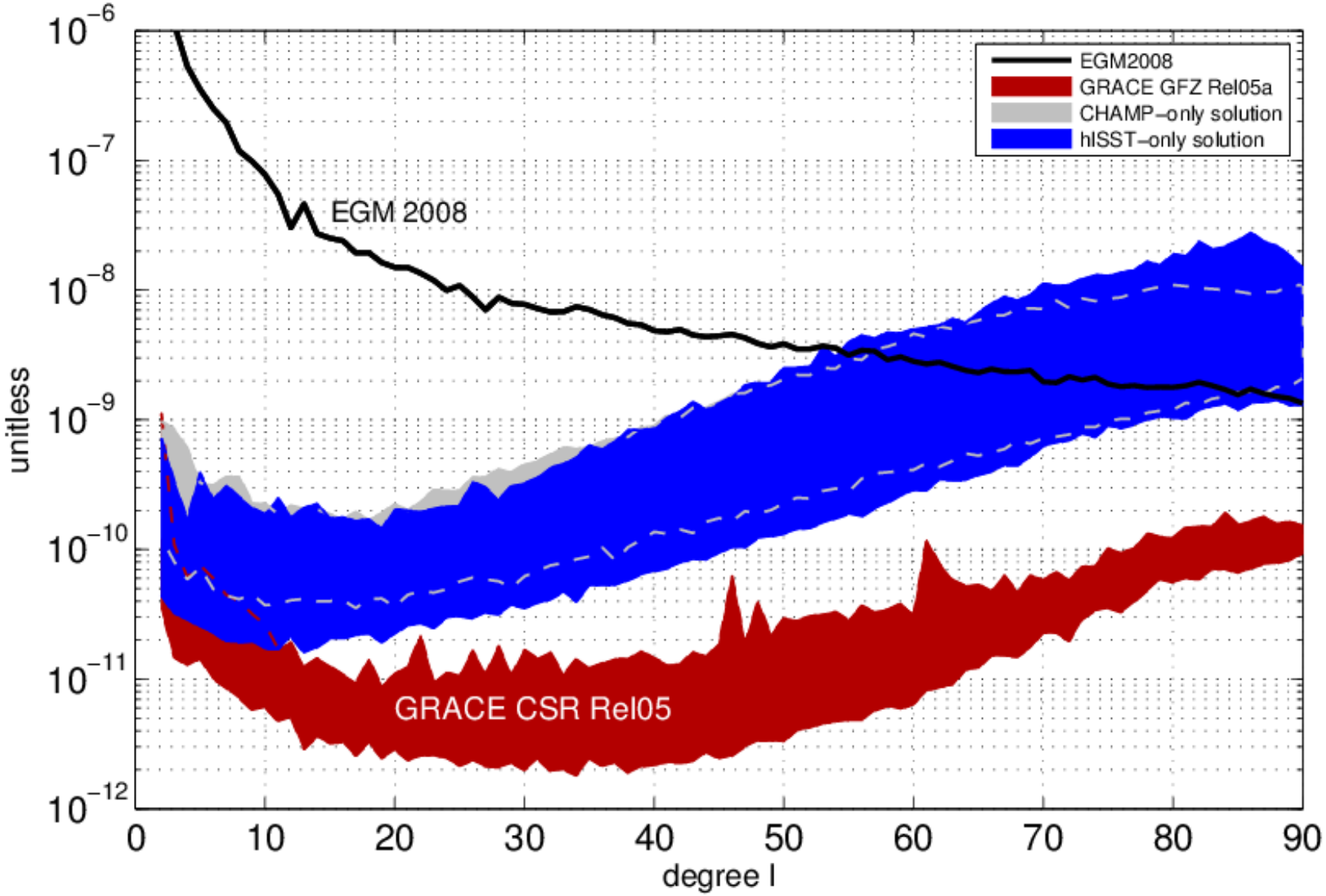
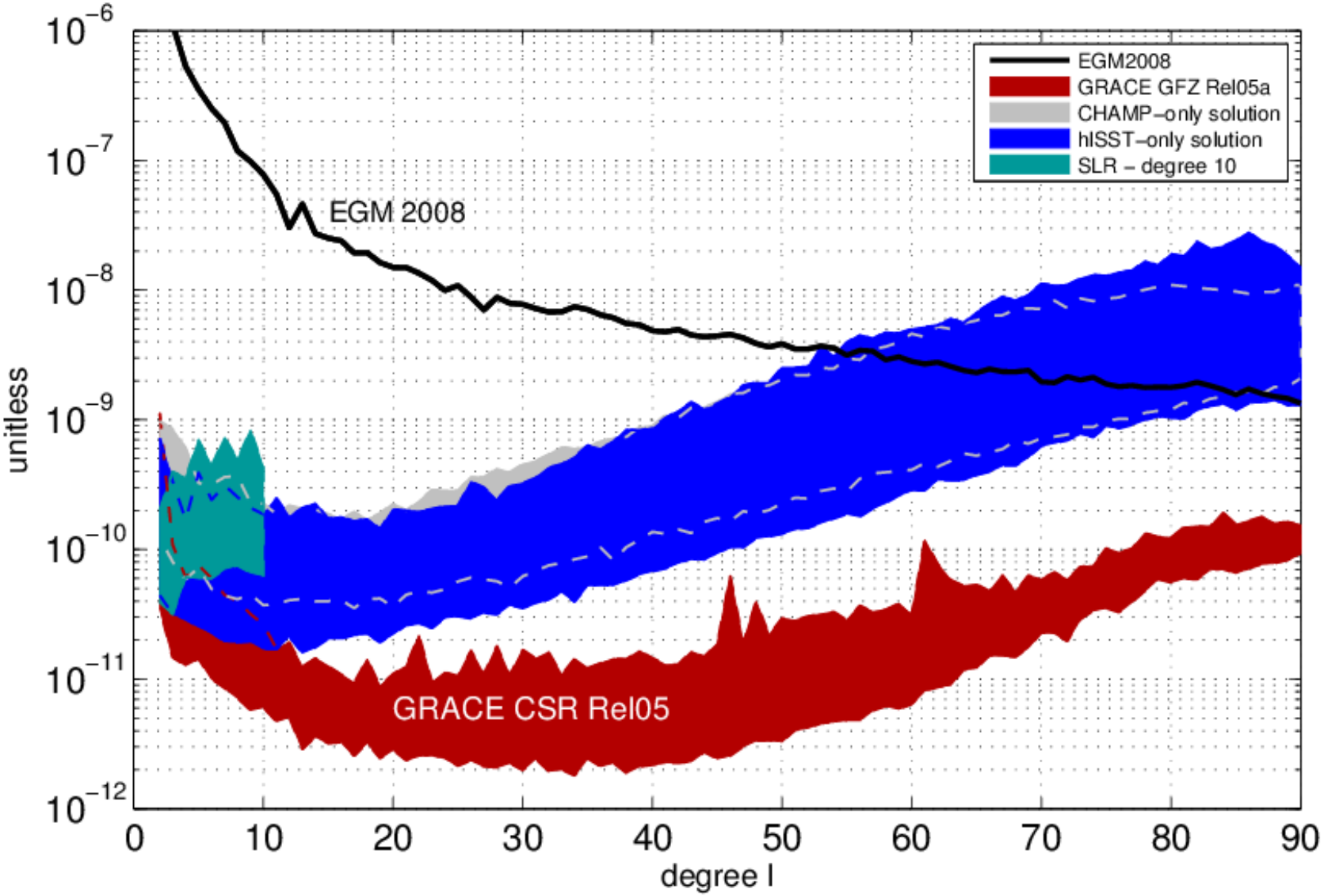
Combined hlSST



Combined hlSST vs SLR



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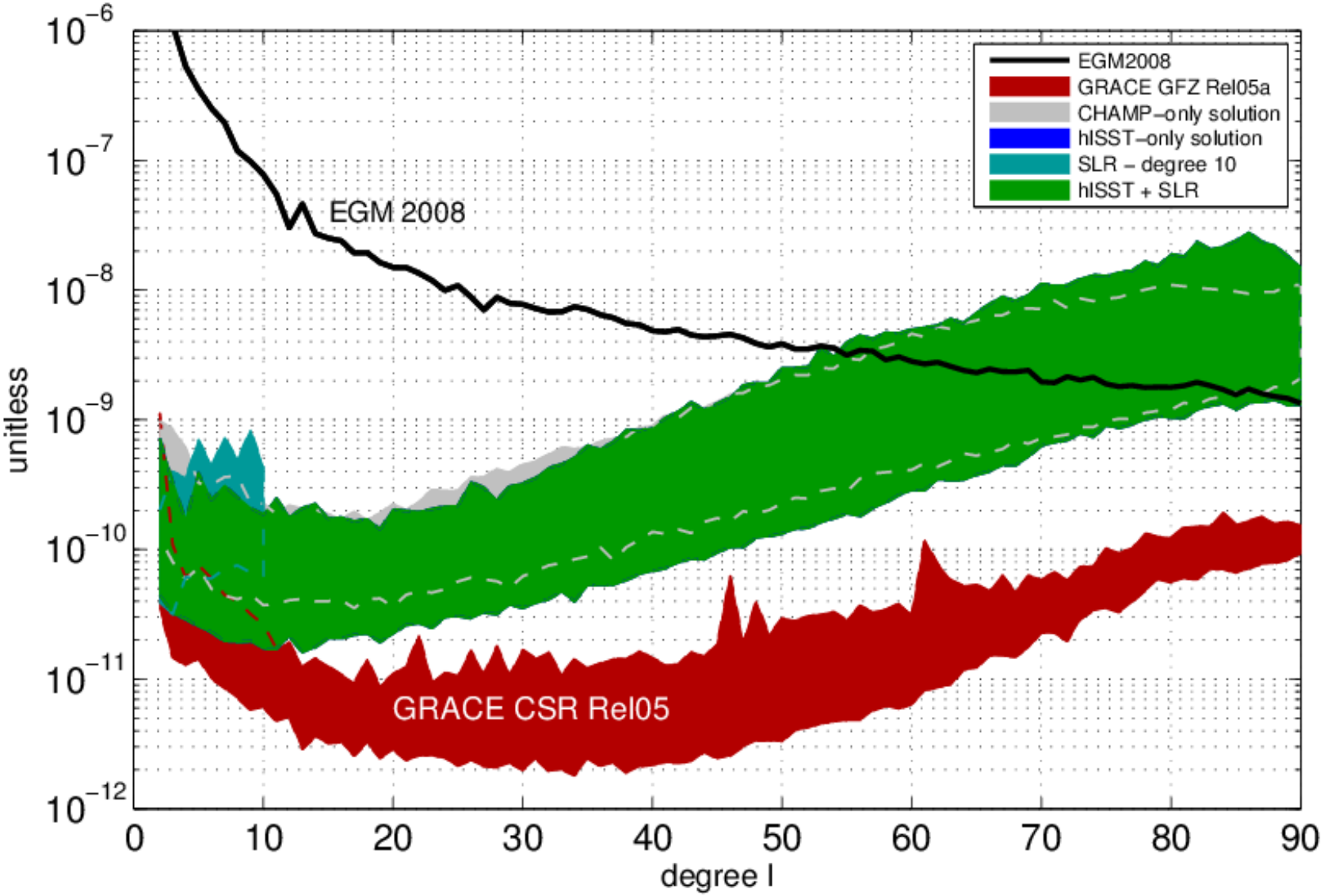
hISST + SLR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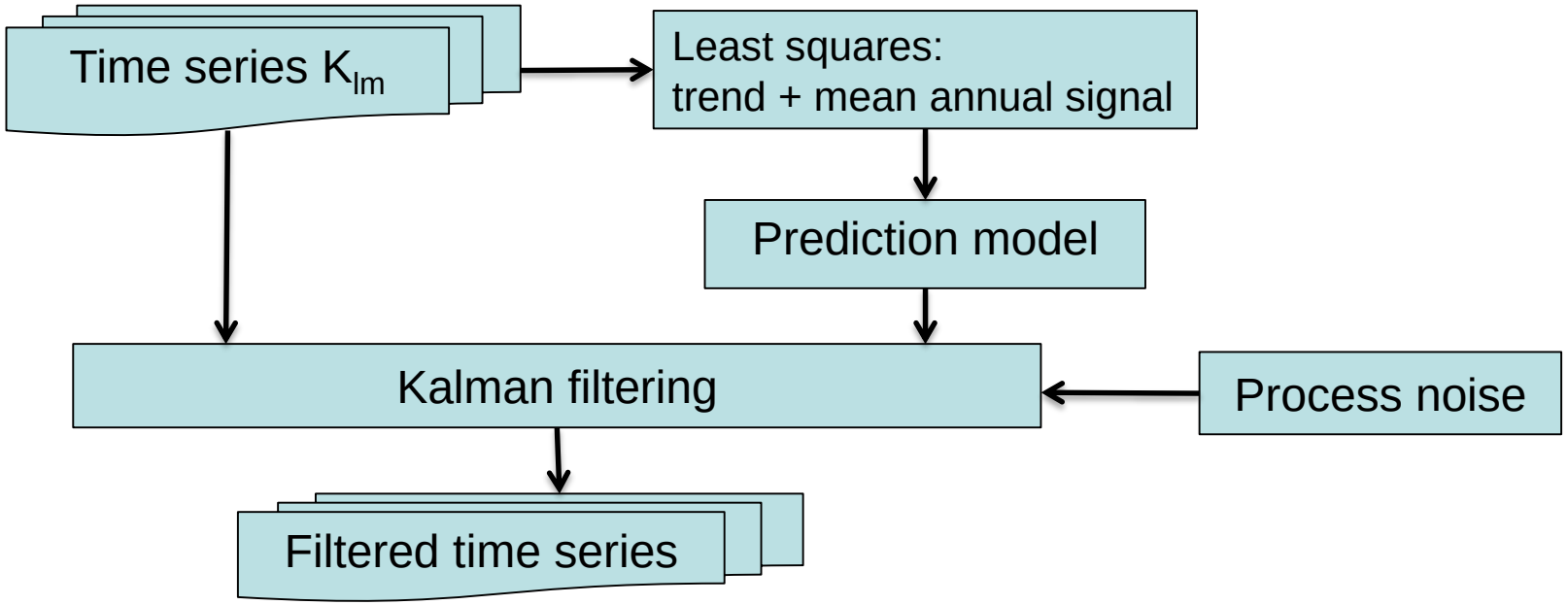
90

Post-processing: old approach

- Kalman filtering

  … allows to handle small numbers of sample (filter warm-up issue).



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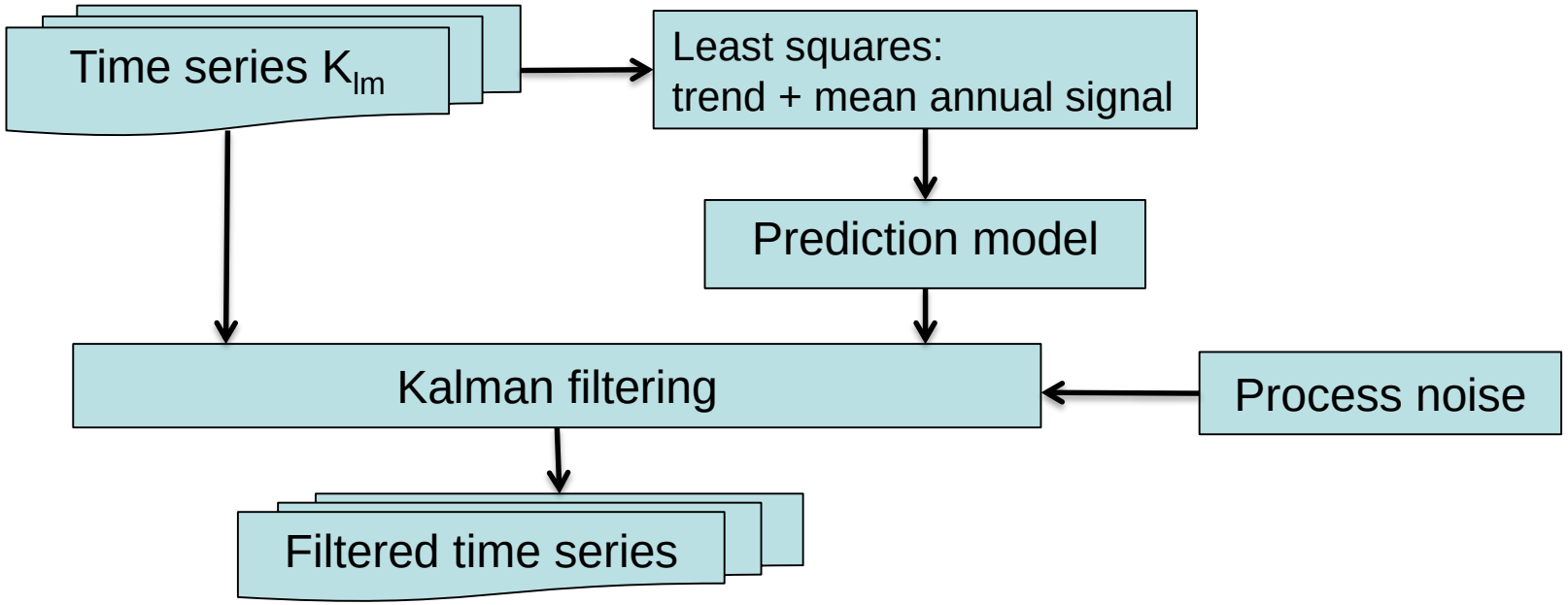
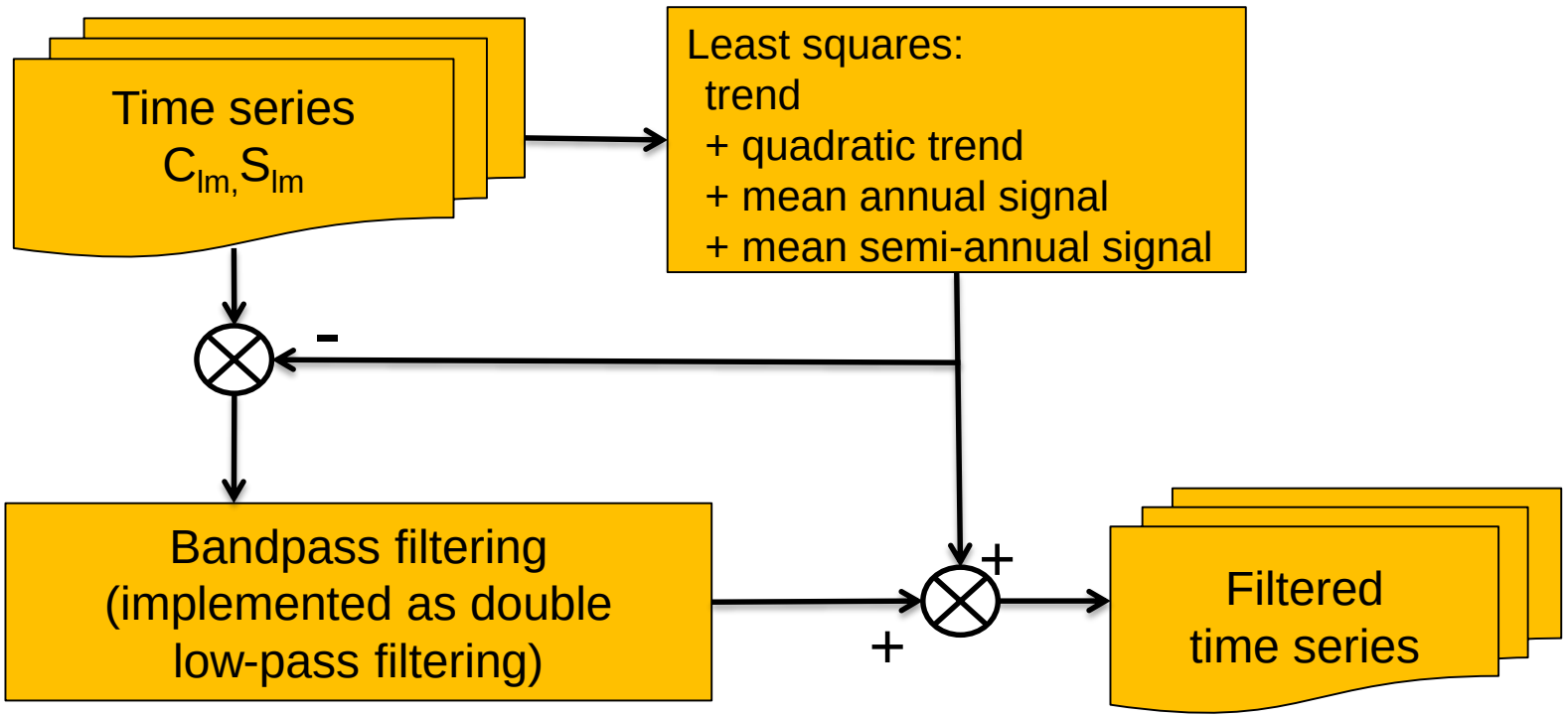


  … is equivalent to an AR(2) process: filter design is limited.

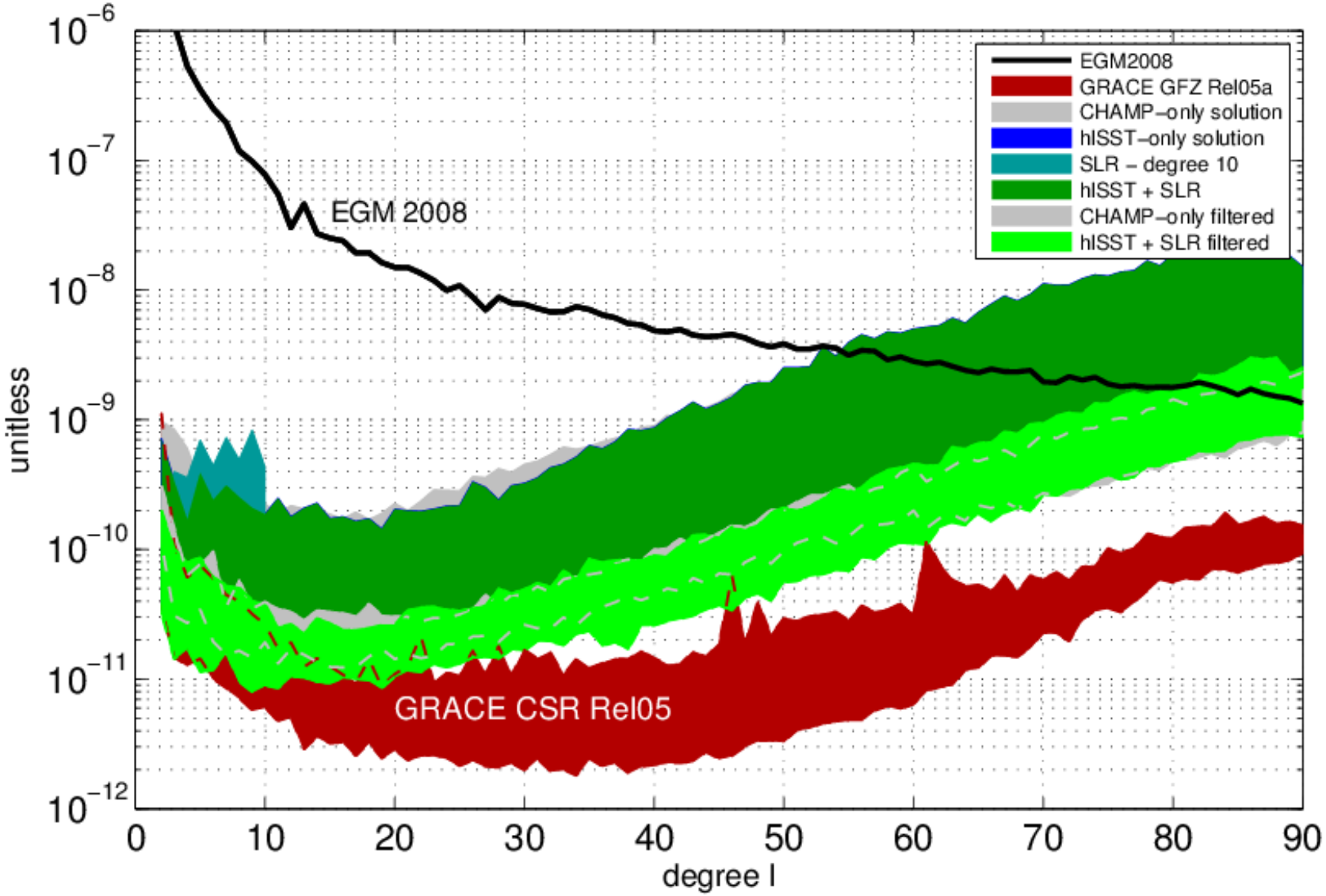
Post-processing: new approach

- Bandpass filtering

  … is possible due to the longer time series (11 years)



hlSST + SLR + post-processing

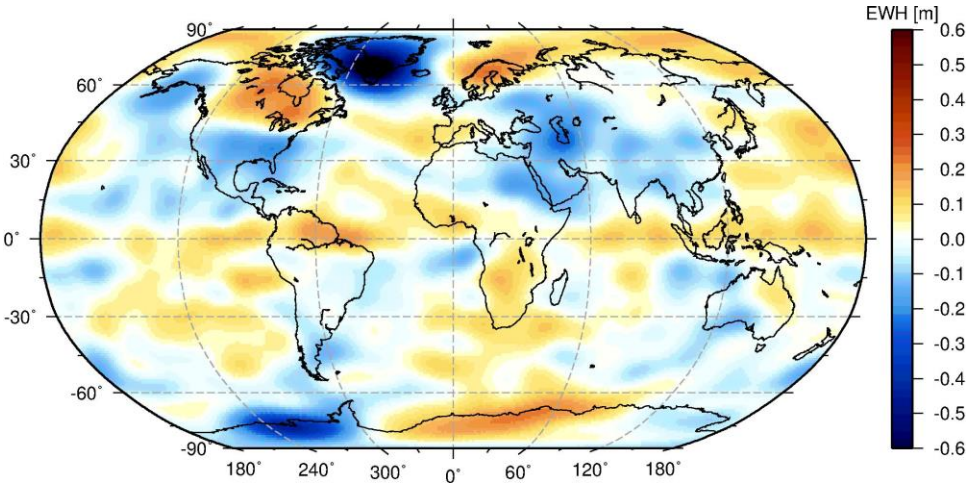


MASS TRENDS
AND ANNUAL SIGNALS

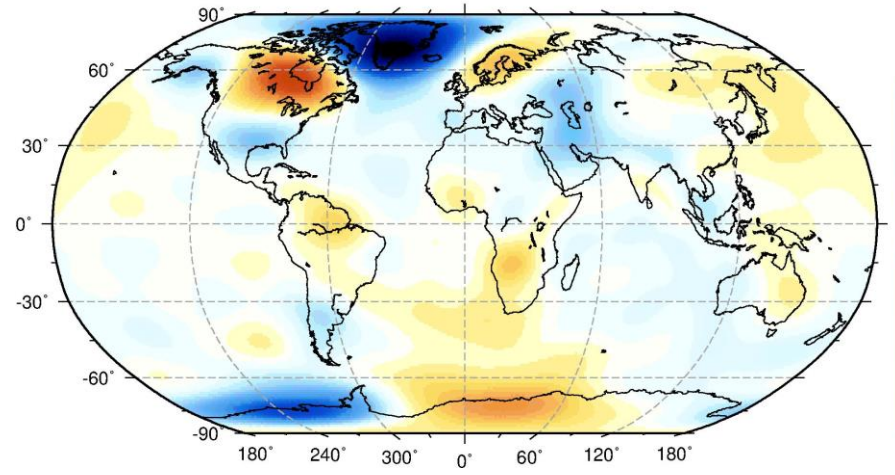
Trends

- Total change in terms of EWH
- Gaussian filtering with 750 km

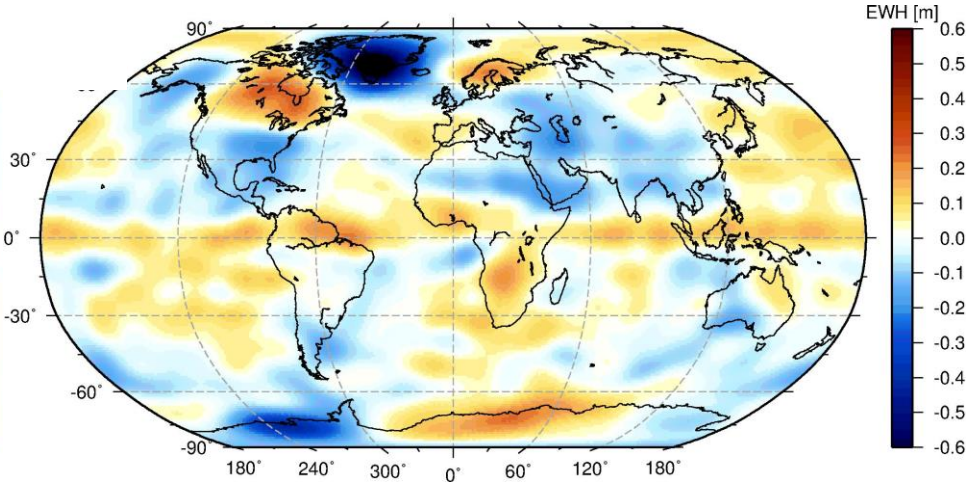
hlSST-only



GRACE CSR



hlSST & SLR



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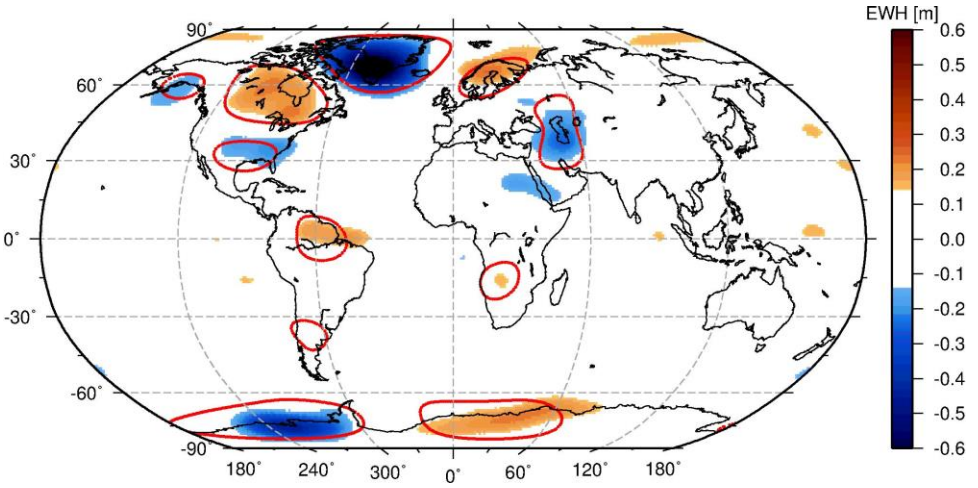

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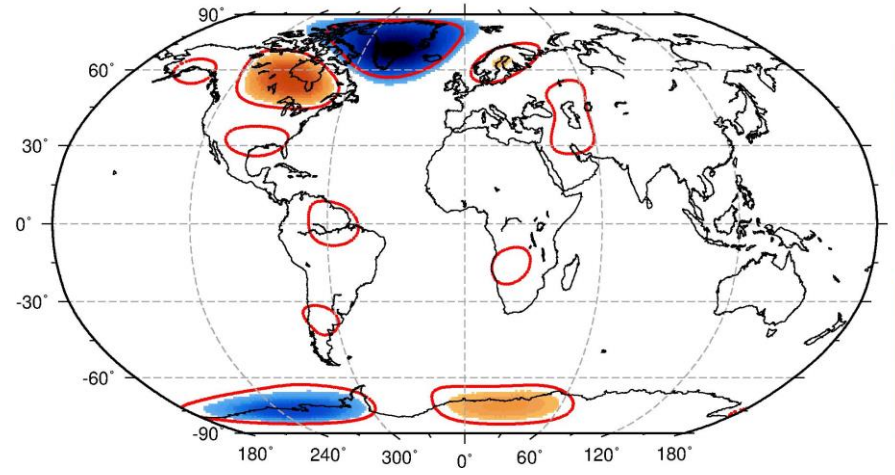

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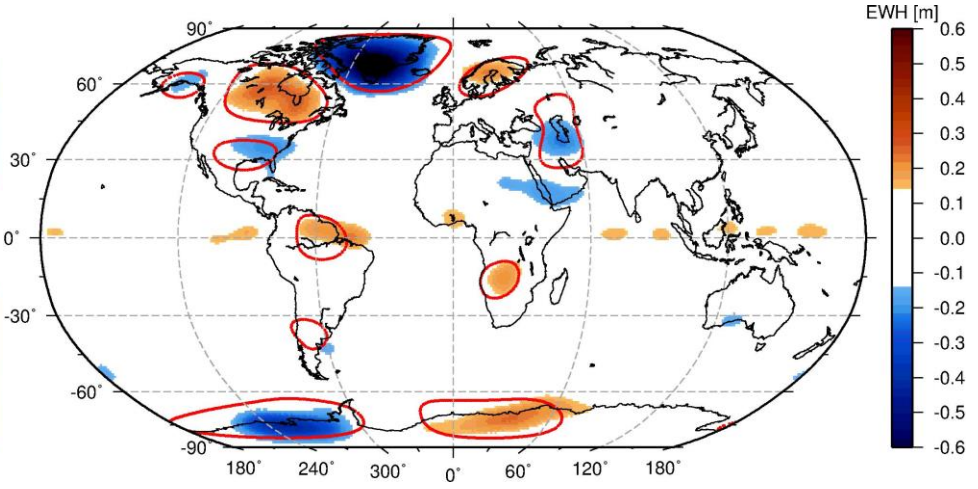

Trends

Mass change rates in [Gt/yr] of areas with the strongest signals

Region	hISST-only[a]		hISST + SLR		GRACE CSR[a]
		ΔGrace		ΔGrace	
Greenland	-252 ± 10	-12%	-267 ± 12	-6%	-285 ± 10
Greenland ext.[b]	-275 ± 12	-13%	-294 ± 12	-7%	-316 ± 10
Canadian Shield	152 ± 10	-12%	158 ± 6	-8%	172 ± 6
West Antarctica	-127 ± 10	-10%	-119 ± 10	-15%	-140 ± 10
East Antarctica	103 ± 10	0%	104 ± 10	1%	104 ± 6

[a] C_{20} replaced by values from SLR.
[b] including Iceland, Svalbard, and the Canadian Arcitc archipelago
Uncertainties are give at the 95% (2σ) confidence level.

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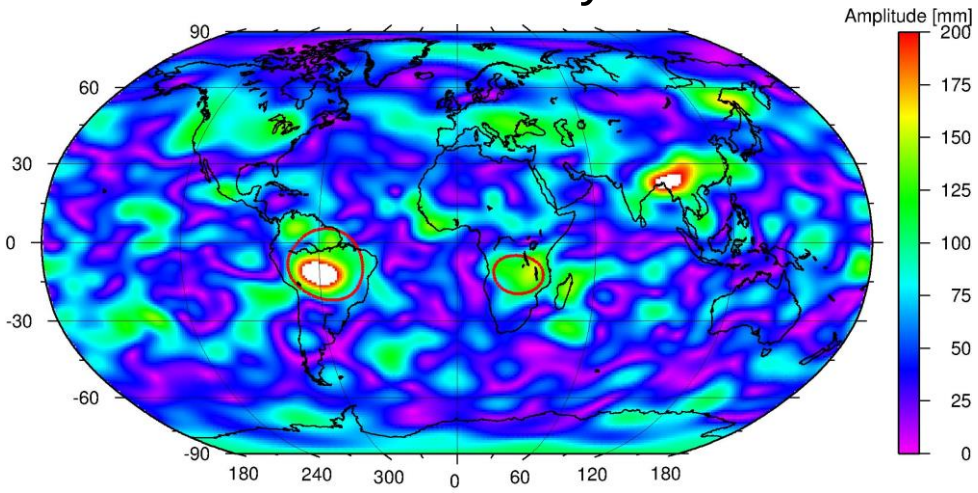
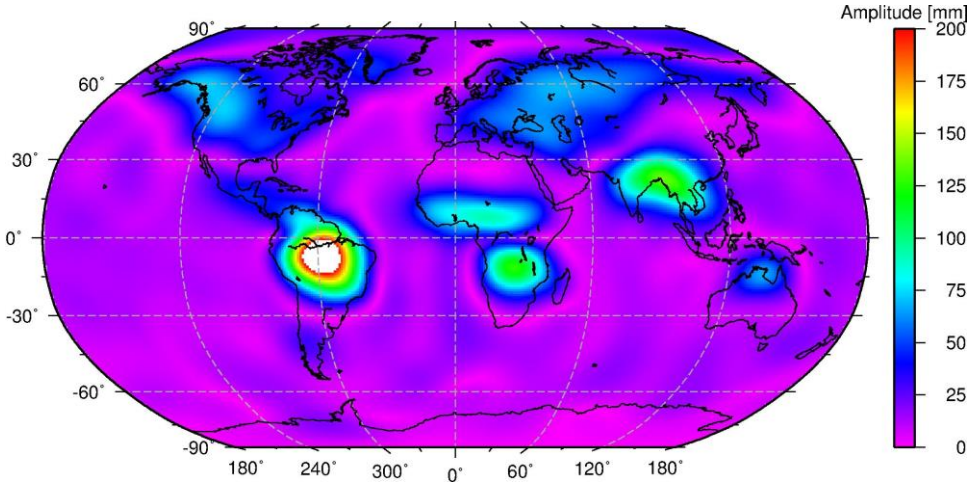
Annual signal

Gaussian filtering with 750 km

CHAMP-only



GRACE CSR



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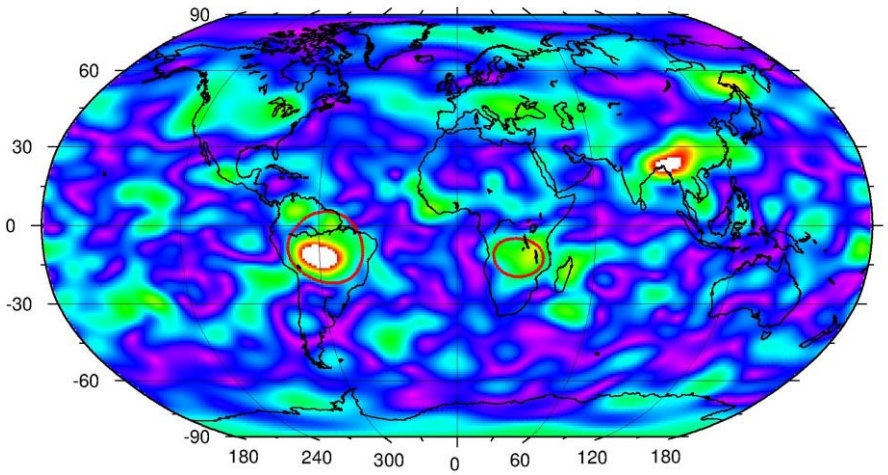
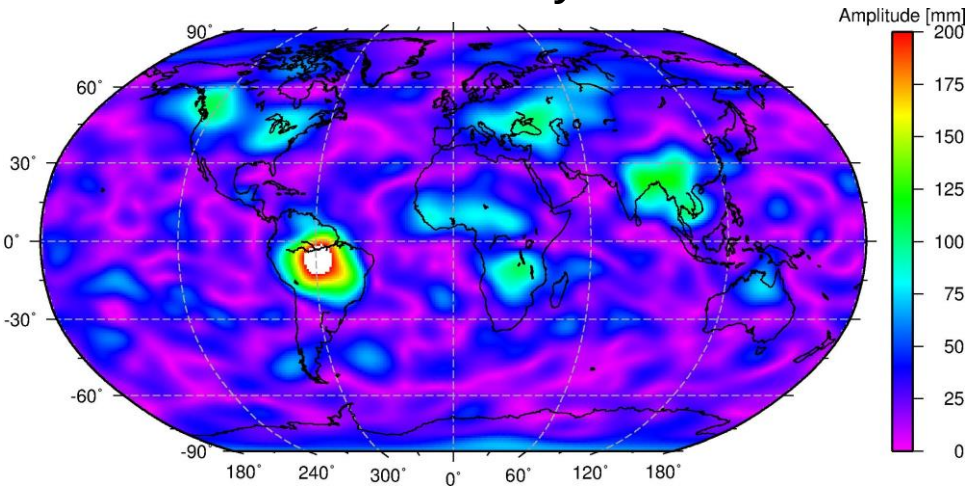


hlSST-only



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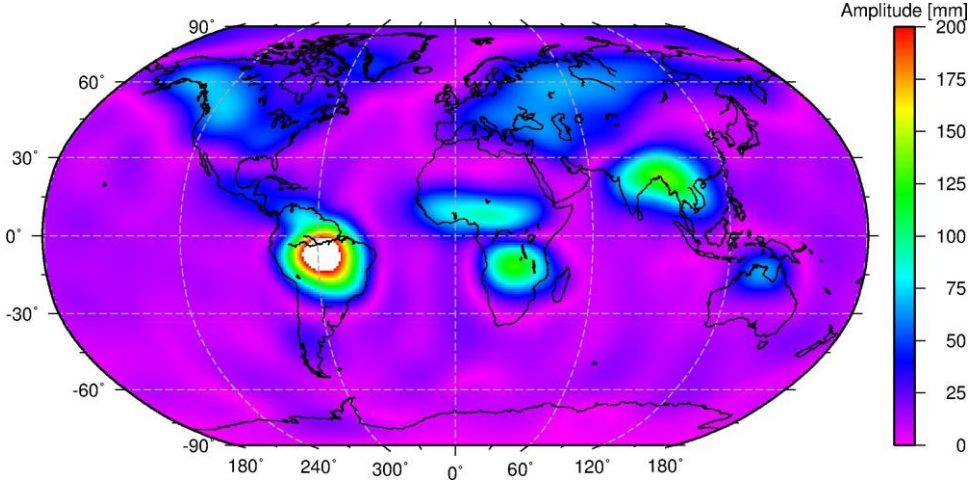

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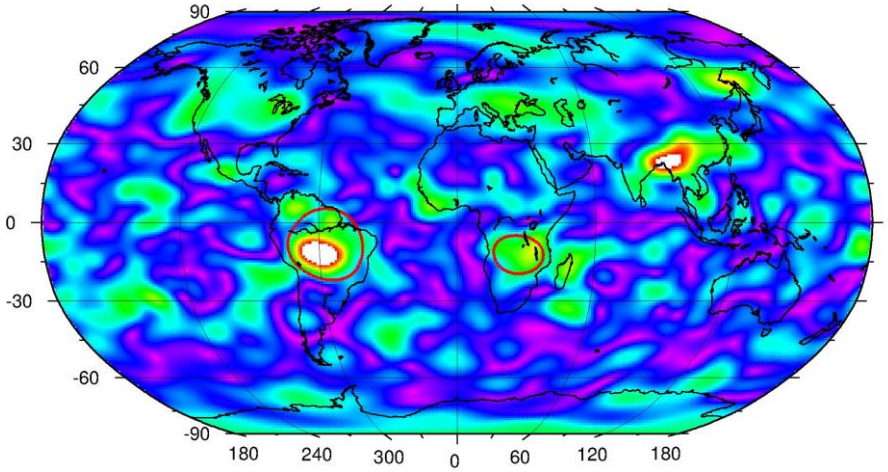

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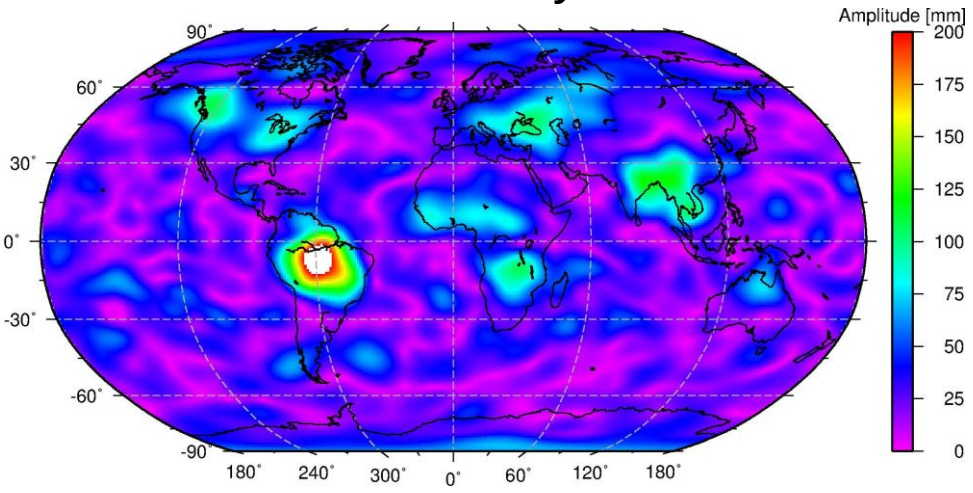

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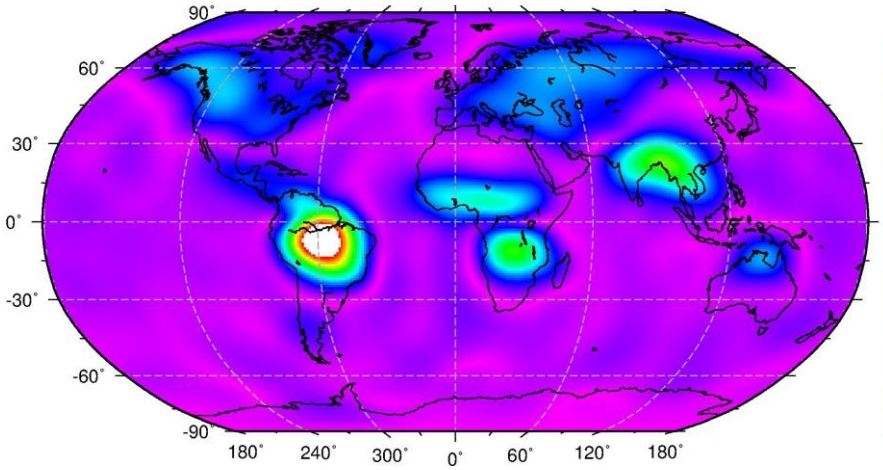
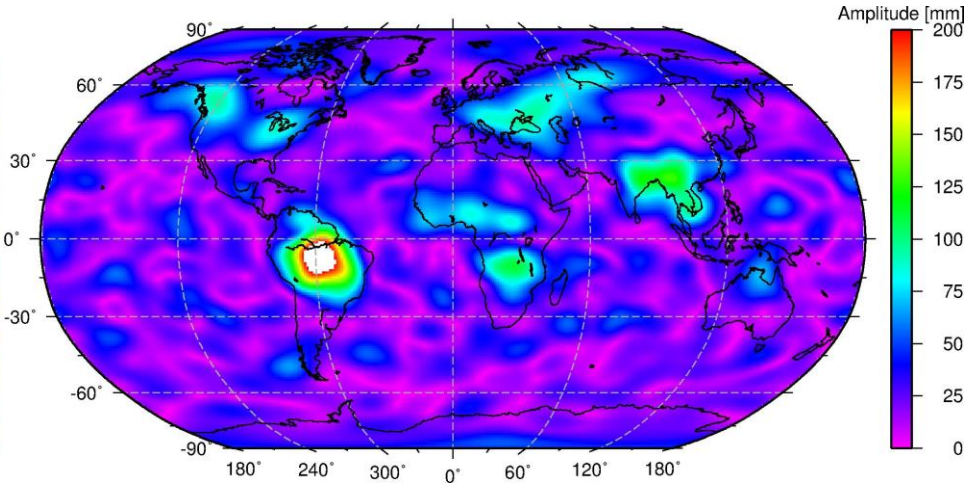


hlSST & SLR



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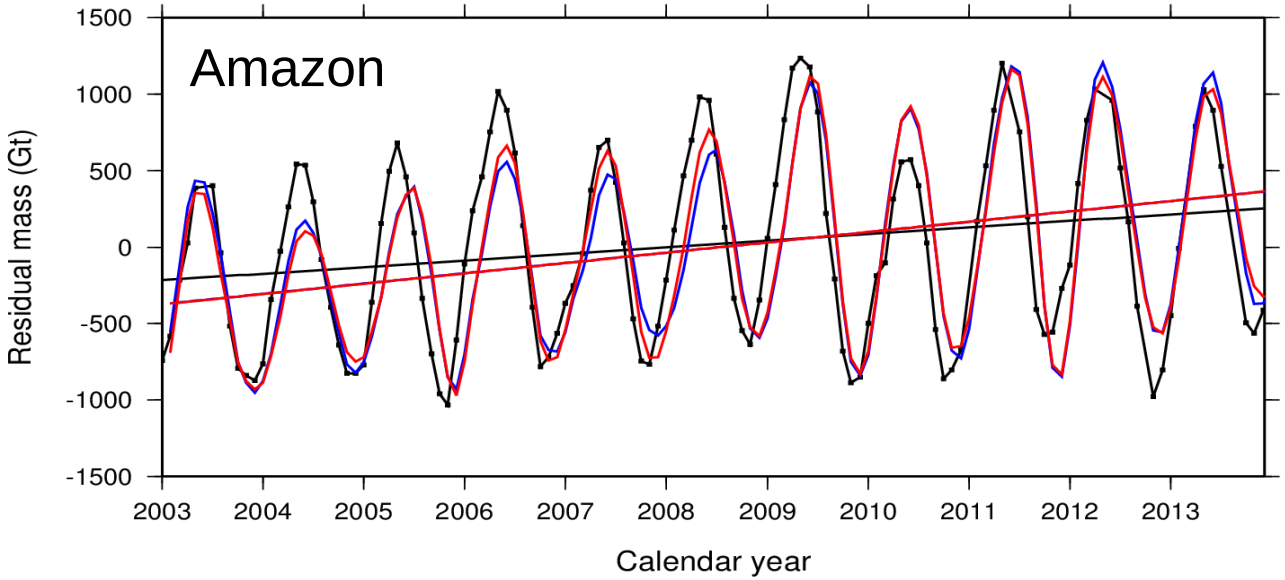
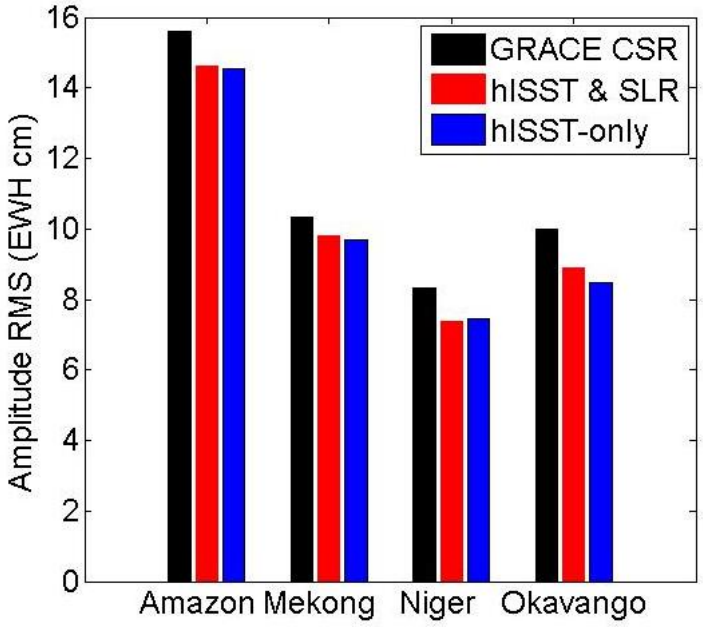
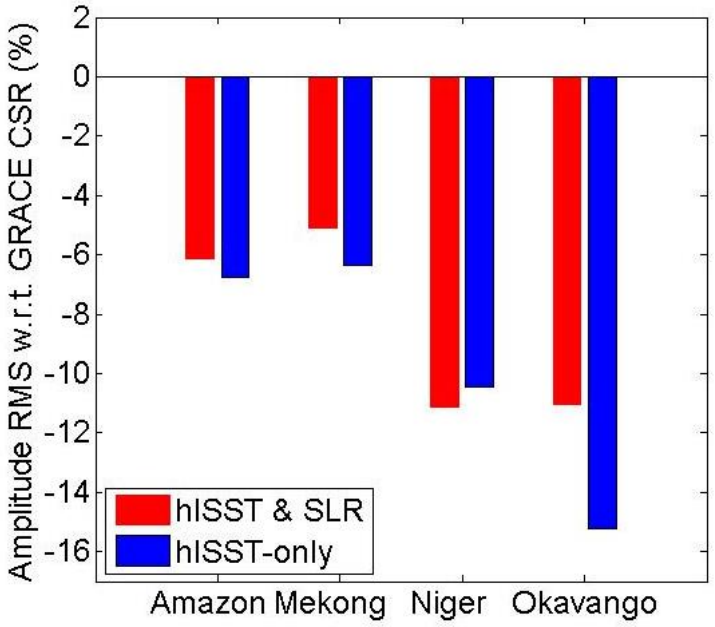






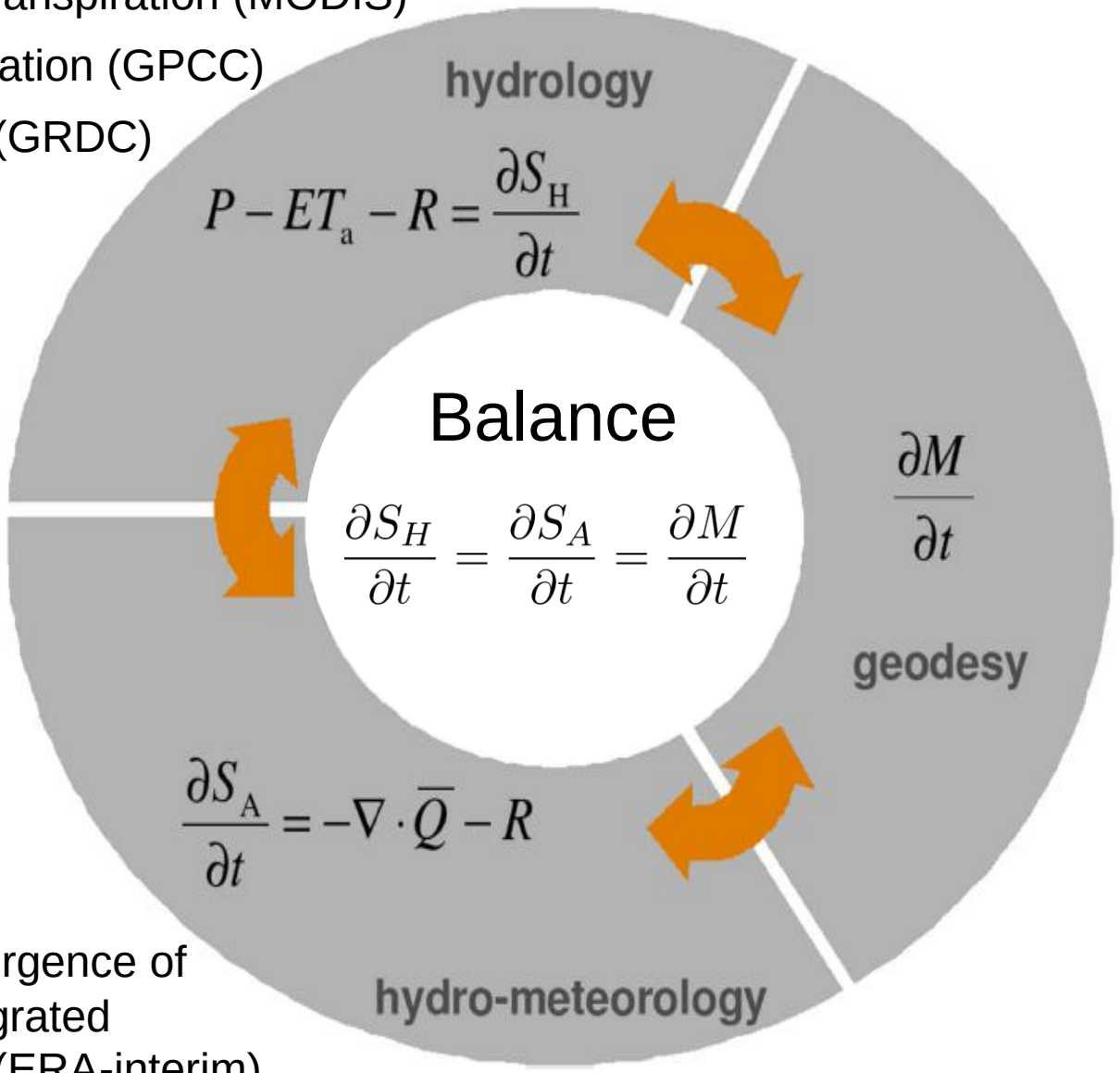
HYDROLOGY AND HYDRO-METEOROLOGY

Mass change as a hydrological observable

ET_a = Evapotranspiration (MODIS)

P = Precipitation (GPCC)

R = Runoff (GRDC)



hlSST+SLR
or
GRACE

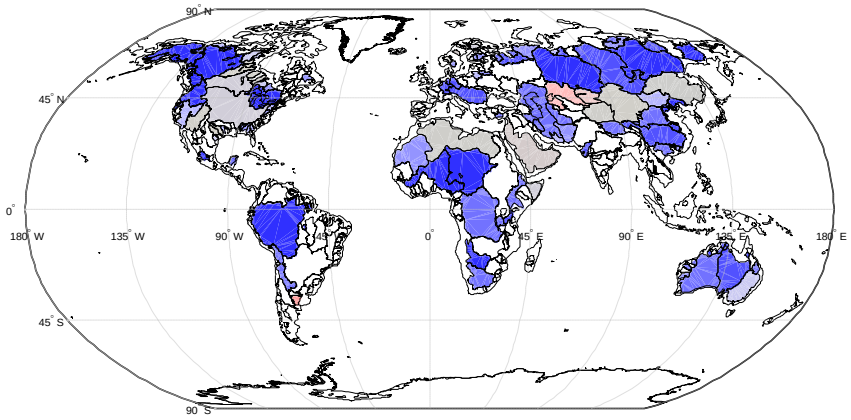
$\nabla \cdot \bar{Q}$ = divergence of vertically integrated moisture flux (ERA-interim)

Hydrological validation: *P-ET$_a$-R*

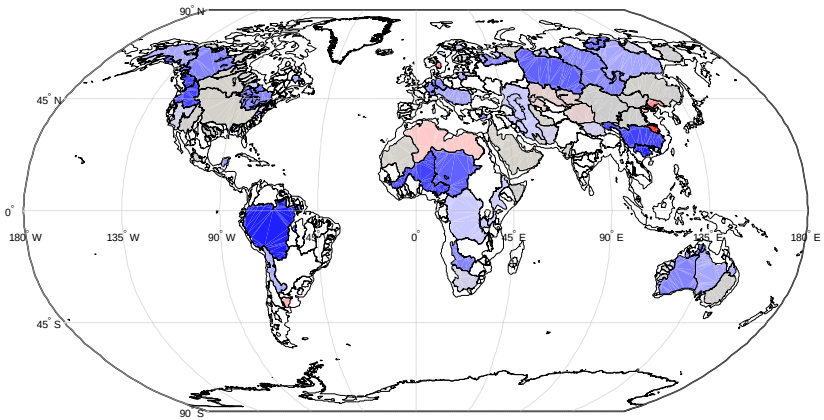
Gaussian filtering with 750km

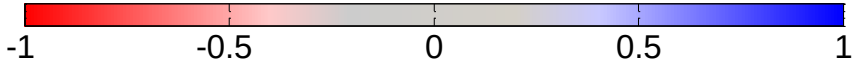
Correlation:

GRACE



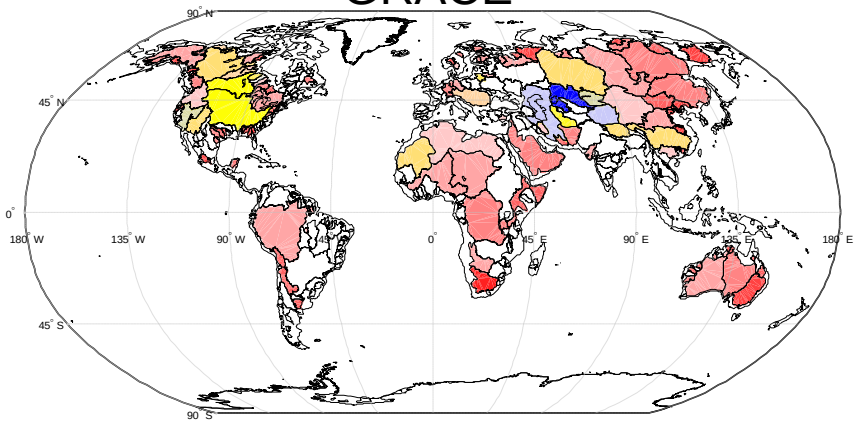
hlSST & SLR



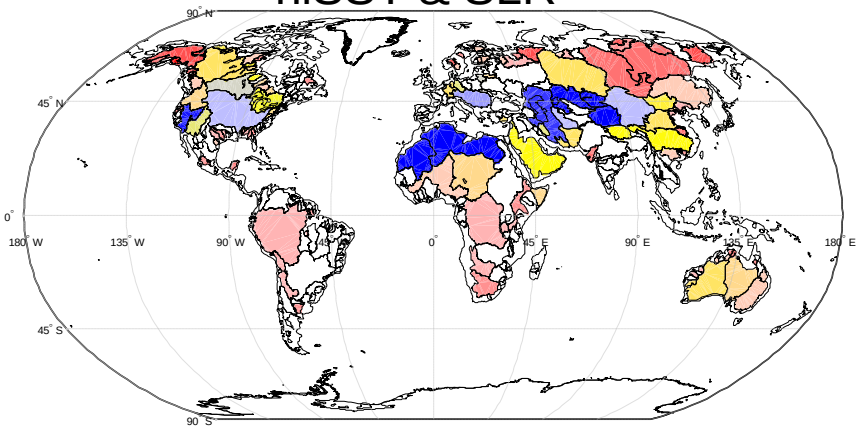


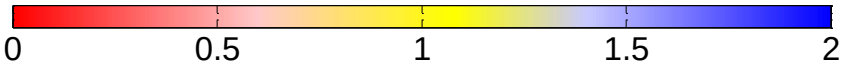
RMS ratio:

GRACE



hlSST & SLR



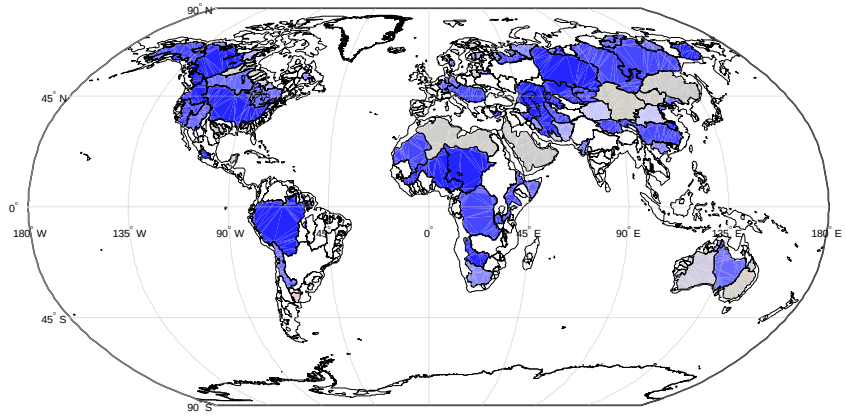


Hydro-meteorological validation: $\nabla \cdot Q - R$

Gaussian filtering with 750km

Correlation:

GRACE



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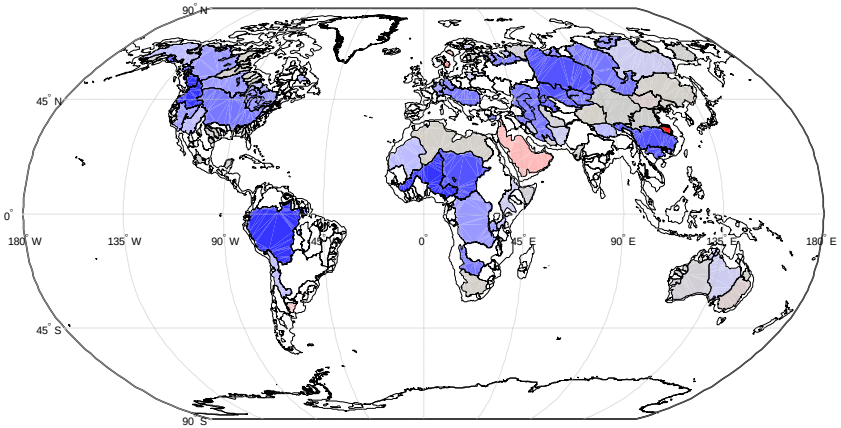

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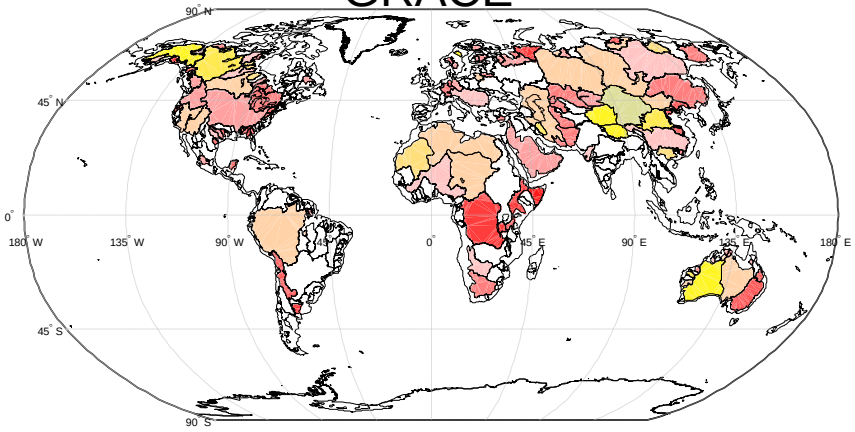
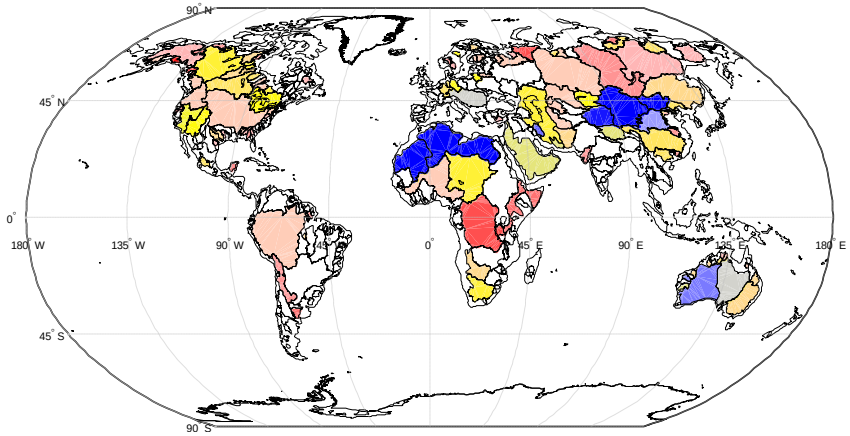
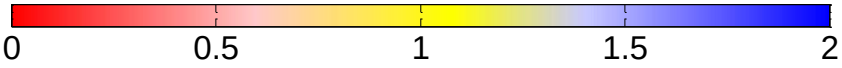
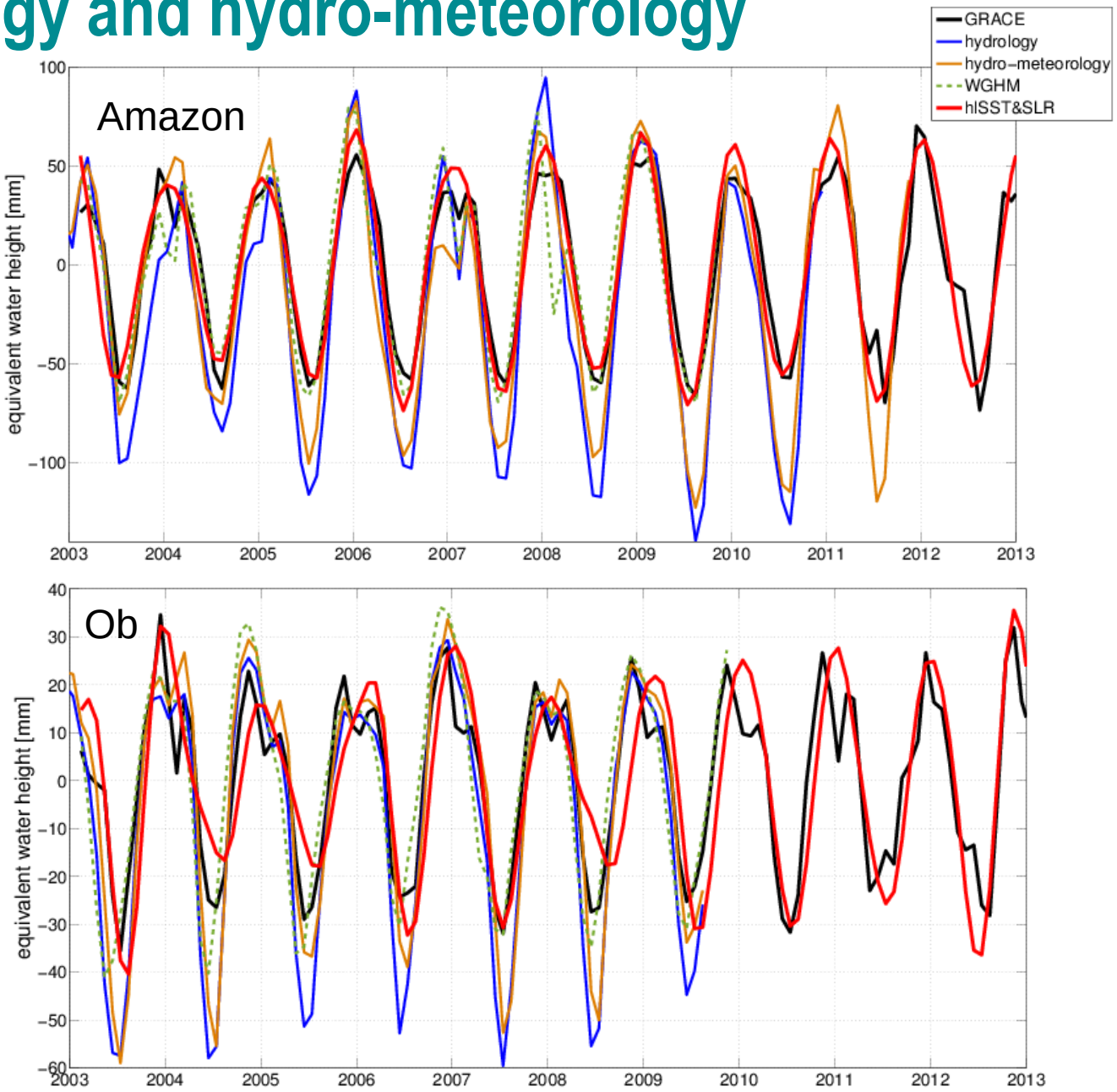


hlSST & SLR





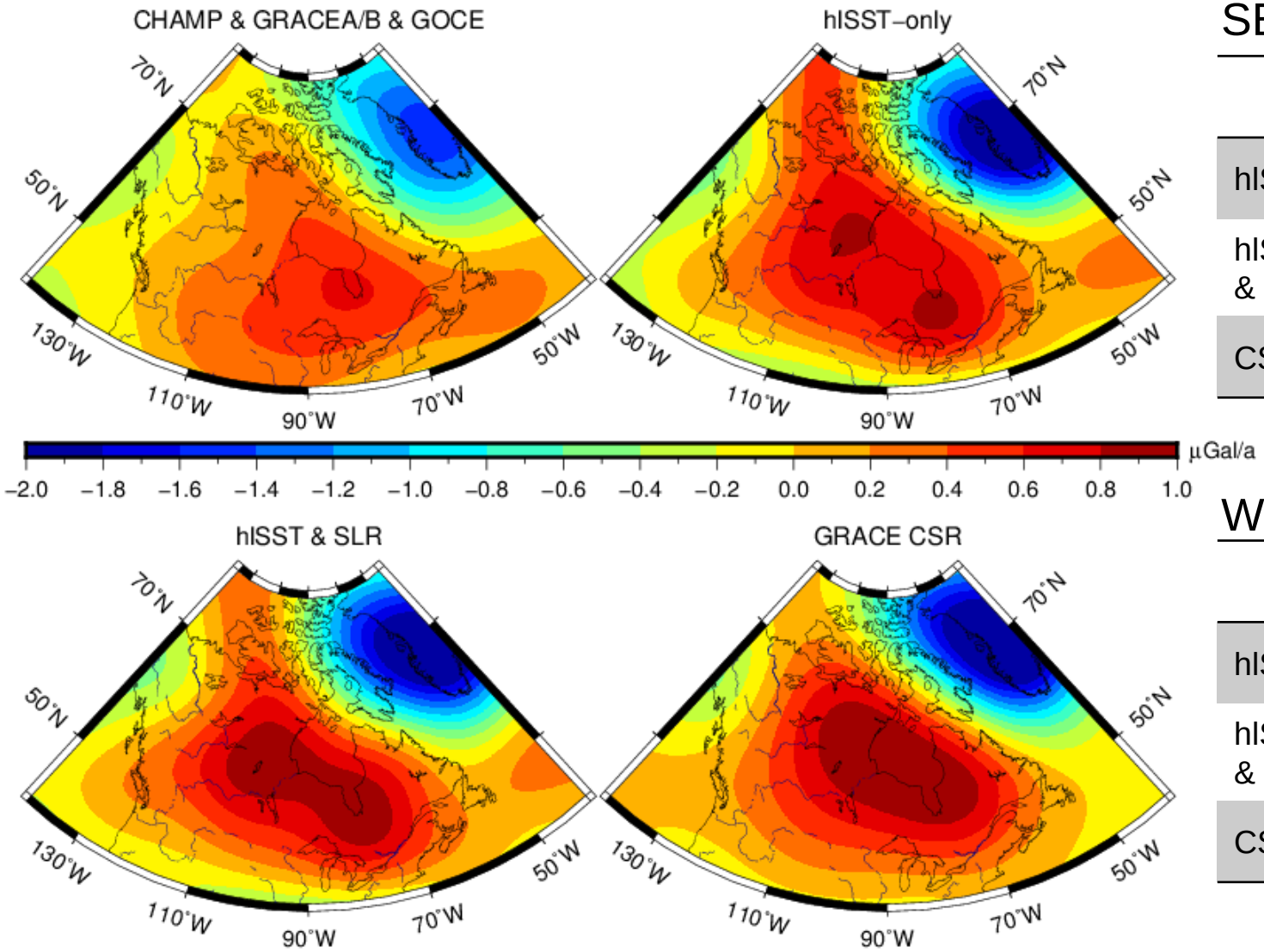
Hydrology and hydro-meteorology



GLACIAL ISOSTATIC ADJUSTMENT

North America

Gaussian filtering with 750km



SE maximum:

	φ	λ
hlSST	49°N	80°W
hlSST & SLR	52°N	80°W
CSR	54°N	75°W

W maximum:

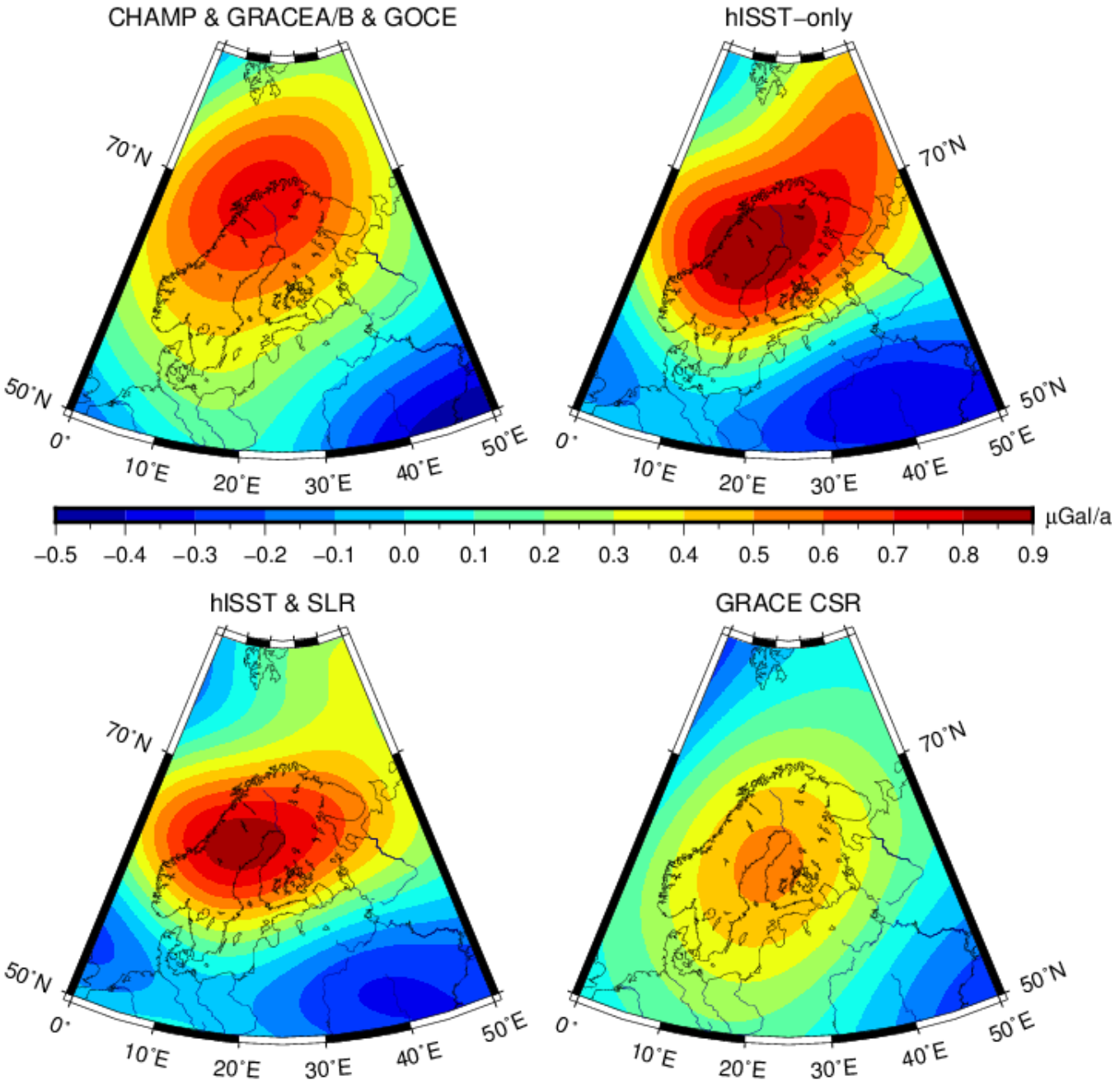
	φ	λ
hlSST	60°N	99°W
hlSST & SLR	58°N	100°W
CSR	63°N	99°W

Fennoscandia

Gaussian filtering with 750km

Maximum:

	φ	λ
hlSST	65°N	18°W
hlSST & SLR	65°N	18°W
CSR	63°N	20°W



HOW GOOD ARE WE THEN?

What can be done:

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- Spatial resolution for the temporally filtered and spatially unfiltered signal is between 1000 to 2000 km
  - … can be improved by spatial filtering – e.g. Gaussian 750km

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- Hydrological signal is similarly underestimated in wet areas. In arid areas the signal is overestimated (SNR!)

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- Mass trend and annual signals are approximately 5-15% underestimated.
- Hydrological signal is similarly underestimated in wet areas. In arid areas the signal is overestimated (SNR!)
- HlSST-only and hlSST+SLR are able to resolve the double peak of the GIA signal in North America. The smaller Fennoscandia is still overestimated.

WHAT ARE THE LIMITATIONS?

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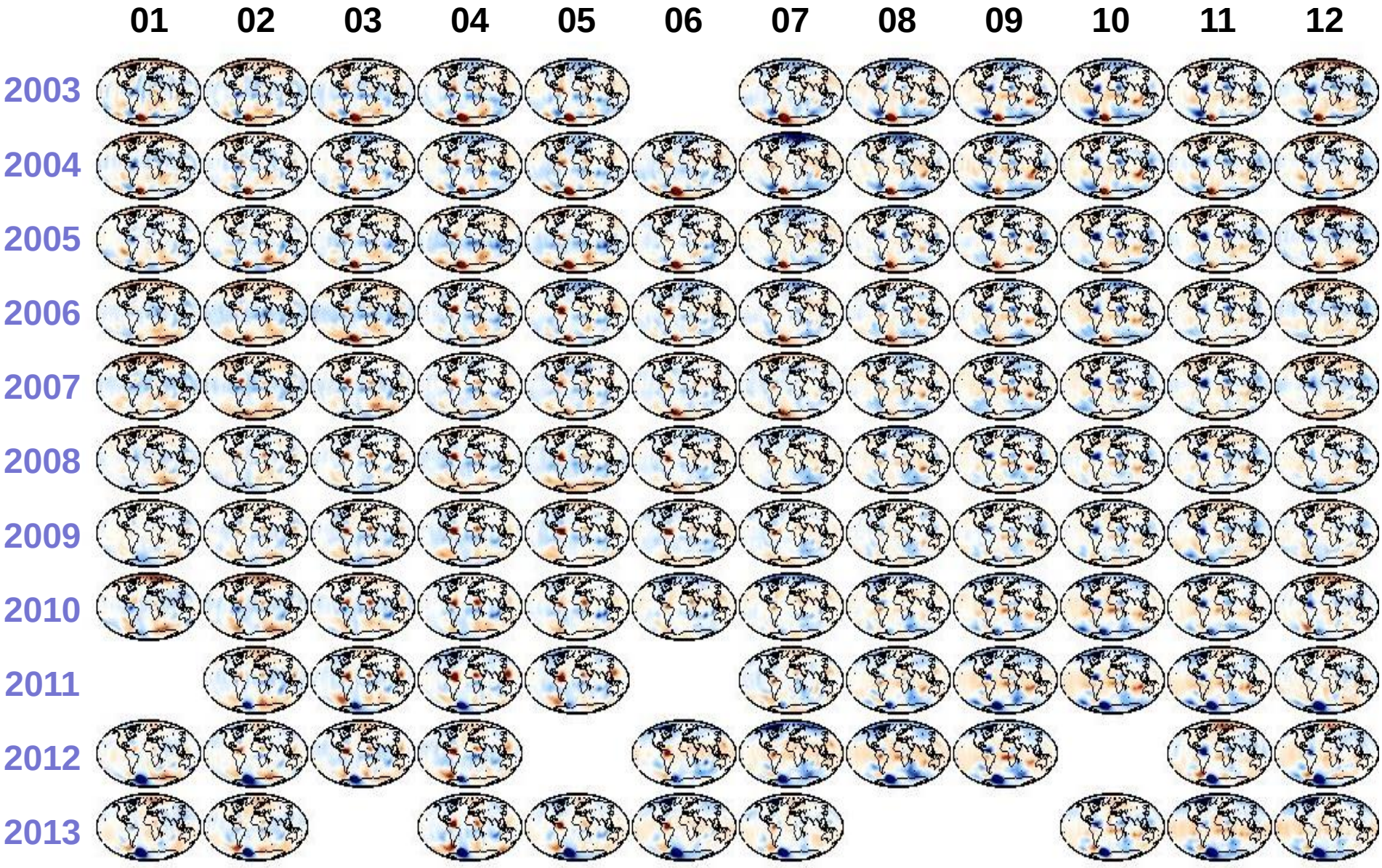
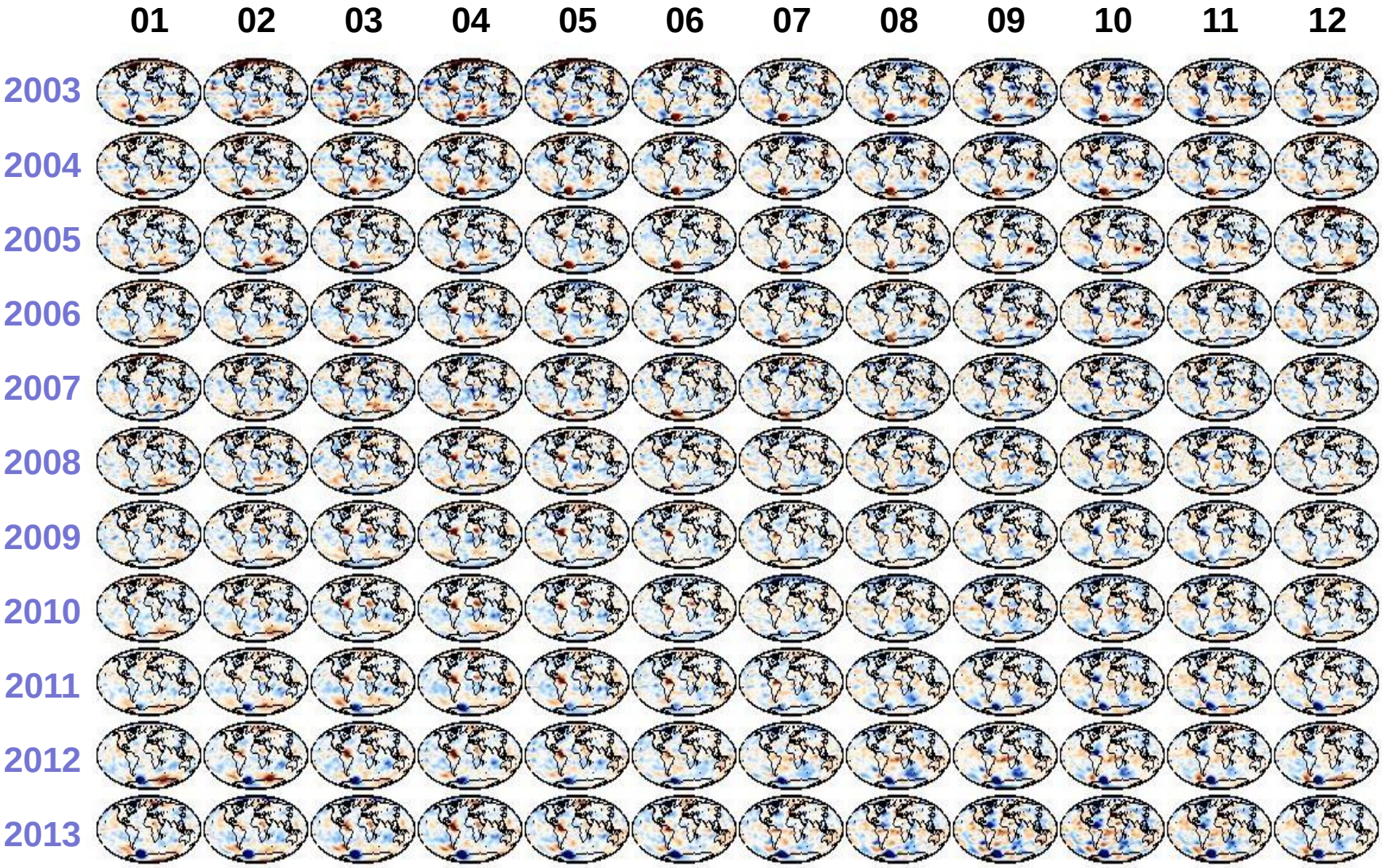
… but the time series can be continued as satellite data will be available throughout the time to GRACE Follow-On

and SLR observations → spatial resolution remains limited

GRACE data availability



hISST + SLR data availability



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About us:
The LGP focuses on four main topics: climate variability, geodynamics, resource management and regional processes. The main objectives are the development of reliable measurement of environmental changes at all spatial and temporal scales, the assessment of the relative impact of human and natural factors in these changes, a better understanding of the relation of the various environmental changes and the evaluation of the risk they induce for mankind. The research relies mainly on the modeling and the interpretation of satellite data.
The LGP is located within the Research Unit in Engineering Science (RUES) at the Faculté des Sciences, de la Technologie et de la Communication, University of Luxembourg. The LGP also hosts the Global Geophysical Fluid Center (GGFC).
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